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Interaction of steel cord – elastomer in radial tyres for passenger vehicles

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Abstract The article focuses on determination of selected material characteristics of samples from different areas of various old passenger tyre casings and on determination of mechanical properties of specific composites with elastomeric matrix and steel reinforcement which are used as steel belts of tyre casing as a sample. These characteristics are used as input data for computational modelling of tyres. It was necessary to carry out various types of experiments to obtain these characteristics. In this article we present the values of the modules of elasticity calculated from the results of DMA tests and static tension tests of samples from old tyre casings and a cohesion test between steel cords and elastomeric matrix. The Mooney-Rivlin parameters, which are necessary input data into computational models of tyres and their parts, were determined from the experimental results. The computational models will be designed to be able to include the effect of aging of the individual tire casing parts. Knowledge of the degradation processes can lead to design and material changes that can increase the resistance of casings against selected forms of degradation processes.

Key words – tire, modulus of elasticity, Mooney–Rivlin parameters, steel cord, elastomer, computational modeling

1. Introduction

Tyres are one of the most important products used in the automobile industry. Therefore, it is important to know how degradation (KOŠTIAL P. 2012) caused by ageing and by the influence of ozone will affect their mechanical properties and behaviour after several years.

For the input parameters in computational models of tyres and tyre parts, as well as for its own verification purposes in order to compare the results of calculations with experimental data, it is necessary to perform a whole set of experiments. Tyre casings are most often modeled using the finite element method. It is therefore necessary to accurately determine the material characteristics of the individual casing parts (KRMELA J. 2008).

This research is focused on the experimental determination of static and dynamic modules of elasticity, M-R parameters and IRHD hardness of selected parts of these tyre casings and cohesion of steel cords and elastomeric matrix and M-R parameters of alluvial mixtures used to rubberizing of steel cords. This data is important material input into computational models of the natural degradation of tyre casings.

2. Experimental procedure

Experimental tests were performed in order to obtain material characteristics and parameters of the selected parts of the tyre casing as important material inputs into the calculations for verification and analysis of computer models with experimental data.

Samples were prepared from treads, alluvial mixtures and sidewalls of three variously aged tyre casings.

Dynamic DMA tests were performed on PYRIS Diamond test device from Perkin Elmer in the temperature range from -70 to 110°C at frequency 1 Hz.

Static test devices for tensile testing Hounsfield H20K-W was used for the mechanical static tensile test in uniaxial force influence of the load force until the breakage. The loading rate was 20 mm / min and the initial distance between the clamps was 20 mm (VIDO P. 2014). The temperature was 20°C.

Hardness tests were performed using a hand IRHD hardness tester at temperature 20°C.

Rheometric analysis of given rubber blends before the vulcanisation of elastomer mixtures was performed. We determined that the vulcanisation characteristics of the alluvial mixtures by using rheometric analysis, performed in accordance with international standard ISO 3417. Data obtained from rheometric analysis of a given rubber mixture, is the time of vulcanization (30 minutes), temperature (150°C) and pressure of vulcanizing press (20 MPa). The loading rate was set for 25 mm / min and the initial distance between the clamps was set for 80 mm.

3. Results and discussion

Dependencies of dynamic modules of elasticity from the temperature obtained from DMA tests are shown in Figures 1 and 2.

From the dependencies of load force from elongation, static modules of elasticity were calculated. Their values for each sample are shown in Table 1.

Table 1. Values of E of the samples at temperature 20°C

Sample	*E* 05 (mid. aged) [MPa]	*E* 17 (oldest) [MPa]	*E* MP44 (new) [MPa]
Tread	5.34	11.22	20.07
Sidewall	1.02	1.52	0.65
Alluvial mixture	2.73	2.01	1.34

Source: VIDO P. 2013

In Table 2 are shown the values of the dynamic modulus E* for the temperature 20°C.

From the results it can be seen that the dynamic modules have much higher values than the static ones. This is caused by dynamic stress which always has higher values than dynamic stress.

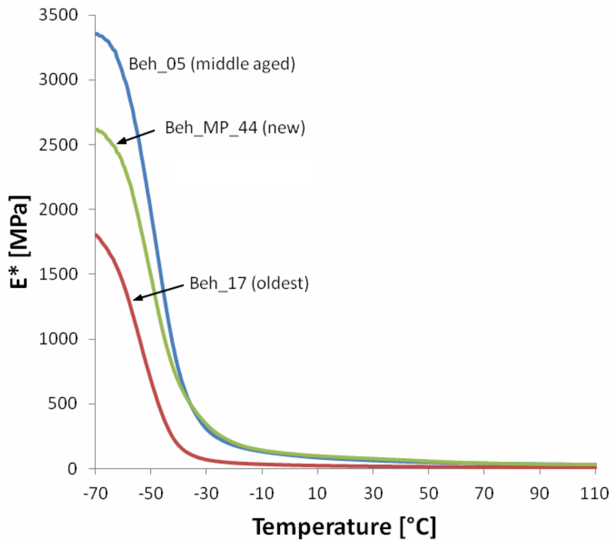

Fig. 1. Dependency of elastic modulus E of treads from temperature.*

Source: PASTOREK M. 2014

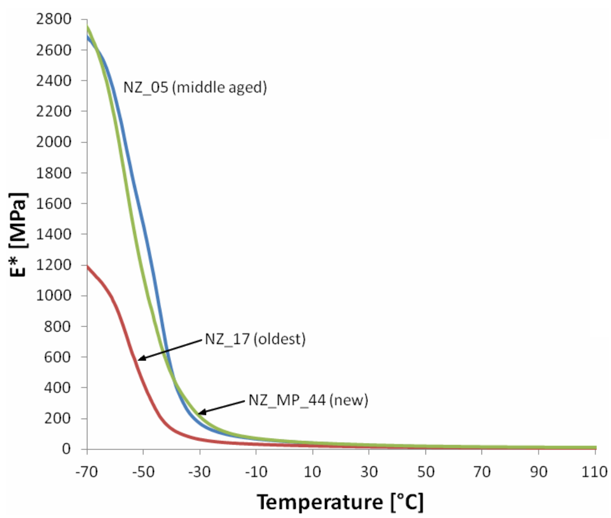

Fig. 2. Dependency of modulus E of alluvial mixtures from temperature.*

Source: PASTOREK M. 2014

From both dynamic and static tests it can be concluded that the samples from the oldest tyre is significantly degraded.

Table 2. Values of dynamic modulus E at 20°C*

Sample	E^* 05 (mid. aged) [MPa]	E^* 17 (oldest) [MPa]	E^* MP44 (new) [MPa]
Tread	72.70	18.21	86.74
Sidewall	21.06	13.98	33.01
Alluvial mixture	34.79	19.70	33.01

Source: VIDO P. 2013

Figures 3 and 4 show the Mooney–Rivlin dependencies of each tyre casing sample with the calculated values of the M-R parameters C_{01} and C_{10}.

Due to better knowledge of the behavior of system cord–elastomer, the samples with a length of steel cord pressed in a matrix of 20 mm and 50 mm were also subjected to a static test of cohesion.

These dependencies were obtained by calculation from the dependencies of stress δ form elongation ε which were obtained from static tension tests.

These parameters are very important because they will serve as input data into computational models of tyre casing degradation.

Using the IRHD hardness tester the hardness of the various aged tyre casing parts was determined. In Table 3 the measured values of hardness of the given samples are shown.

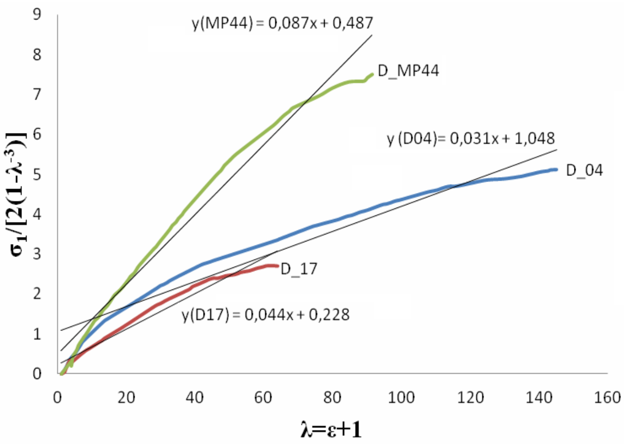

Fig. 3. M-R parameters of tire casing treads.

Source: KRMELA J. 2012

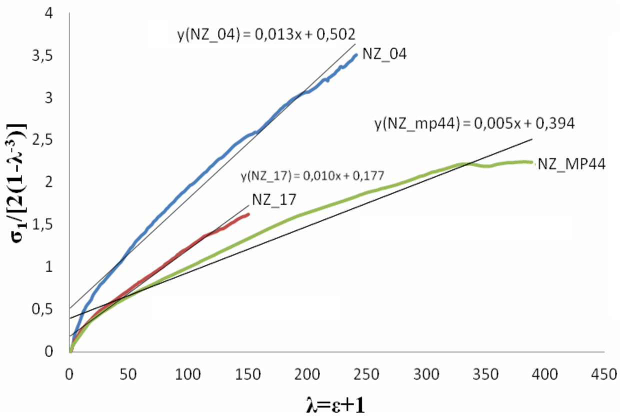

Fig. 4. M-R parameters of tire casing alluvial mixtures.

Source: KRMELA J. 2012

Table 4. Values for alluvial mixtures for rubberizing of steel cords

σ [MPa]	ε [%]	C_{10} [MPa]	C_{01} [MPa]
21.1	272.2	3.321	-1.965

Source: own study

Table 3. Values of IRHD hardness

Sample	*IRHD* MP44 (new) [-]	*IRHD* 05 (mid. aged) [-]	*IRHD* 17 (oldest) [-]
tread	72.83	73.50	79.33
sidewall	43.17	56.67	65.00
alluvial mixture	44.00	51.50	62.17

Source: VIDO P. 2013

Dependencies of the force from elongation for chosen elastomeric samples are shown in Fig. 5. Curve "a" represents a single cord pulled from matrix, curve "b" represents two cords pulled from matrix at once and curve "c" represents three cords pulled from matrix at once.

Due to better knowledge of the behaviour of the cord–elastomer system, the samples with a length of steel cord pressed in a matrix of 20 mm and 50 mm were also subjected to a static test of cohesion.

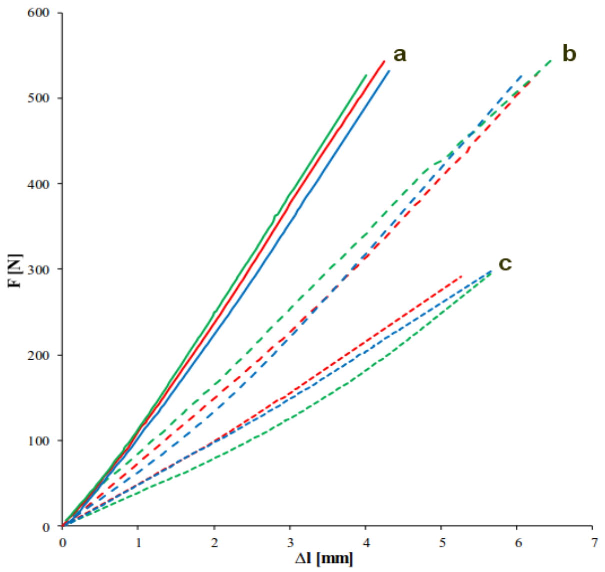

Fig. 5. Dependency of load force from elongation from cohesion test between steel cords and elastomeric matrix. Source: VIDO P. 2014

4. Summary and conclusions

From the dynamic and static experiments modules of elasticity of tread, sidewall and alluvial mixture samples were determined and compared. The results show that the dynamic modules have much higher values than the static ones. This is caused by dynamic stress which always has higher values than dynamic stress.

From both dynamic and static tests can be concluded that the samples from the oldest tyre casing is significantly degraded.

From the results of the IRHD hardness test it can clearly be seen that hardness increases with age. This is most significant in the results for tread samples. From all of the results it can be concluded that the oldest tyre casing is significantly degraded.

Selected elastomeric samples represent the alluvial mixtures for rubberizing steel cords that are used in the production of steel cord belts in car tyre casings for passenger cars.

For a test of cohesion between the elastomeric matrix and steel reinforcement, it is necessary to know the tensile strength of steel cords so that we know whether there is a destruction of the adhesive bond in the system cord–elastomer or there is rupture of reinforcement.

The results mentioned in the article are part of research of computational modeling related to pulling of cords and they are also connected to verification with the respect of the experiments. Therefore, the obtained results will be used as parameters for the calculation of car tyre casings or specific parts of tyres – steel cord buffers and they will be compared to the data obtained experimentally.

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References

1. KOŠTIAL P., KRMELA J., FRYDRÝŠEK K., RUŽIAK I. 2012. *The Chosen Aspects of Materials and Construction Influence on the Tire Safety. Composites and Their Properties*. Chapter 13. Ning Hu (Ed.), Croatia: InTech, Rijeka, pp. 265-298, ISBN 978-953-51-0711-8, DOI: 10.5772/48181.
2. KRMELA J. 2008. *System approach to computational modeling of tires*. Czech Republic, Brno, ISBN 978-80-7399-365-8. (in Czech)
3. KRMELA J., et al. 2012. *Determination of Mooney-Rivlin Parameters of Alluvial Mixtures of Steel cords as an Input for FEM Models of Tire*. „Hutnícke listy“. Vol. 65 No. 7, pp. 104-106.
4. PASTOREK M. 2014. *Verification of experimental results of selected material characteristics of passenger tire casings*. Dissertation thesis. Slovak Republic, Púchov (in Slovak).
5. VIDO P., et. al. 2013. *Determination of material characteristics for verification of computational models of tires*. „QUAERE“, Czech Republic, Hradec Králové, pp. 2611-2616.
6. VIDO P. 2014. *Specific composites with polymeric matrix from the aspect of computational modeling*. Dissertation thesis. Slovak Republic, Púchov (in Slovak).